Understanding Transcrustal Magmatic Systems through Plutonic Lithics

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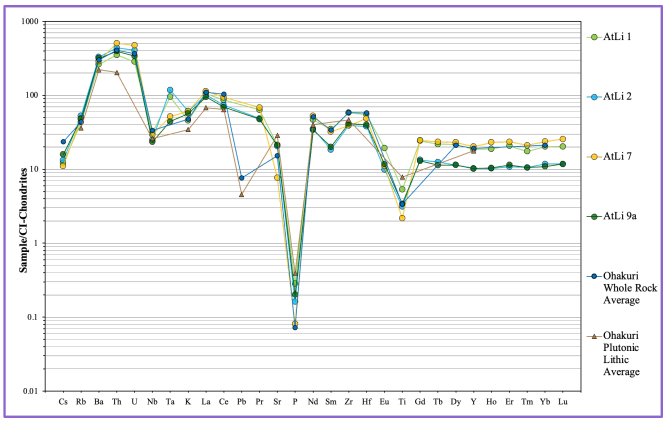
Although volcanoes are well known for their astonishing, potentially devastating processes, there are many gaps in our understanding of how exactly they work. While we know that volcanoes are underlain by magmatic systems that house magma (molten rock), it is unclear how this magma moves around in the subsurface. Generally, when magma is not erupting, it remains underground and cools slowly, crystallizing into rock. We call this crystallized magma a pluton, and define plutonic lithics as coarse-grained, crystalline fragments in exposed rock that originally solidified underground. This summer, I acquired and analyzed data on plutonic lithics that erupted in the Taupō Volcanic Zone (TVZ), New Zealand 240,000 years ago, forming the Ohakuri ignimbrite and caldera.

The TVZ is home to some of the most active and productive volcanoes on earth, generating high rates of rhyolitic magma, which erupt explosively to form large calderas (Wilson et al. 1995). TVZ volcanism occurs due to a rifted arc and the subduction of the Pacific Plate beneath the Australian Plate (Wilson et al. 1995). Beneath the Ohakuri caldera, the TVZ consists of a 5-15 km deep mush zone, containing both melt and crystals. This mush zone becomes more mafic with depth and features layered magma bodies where magma ascends via extraction processes. This mush zone is the proposed origin of our plutonic lithics. Thus, studying plutonic lithics allows us to further the current understanding of the transcrustal magma system that feeds the TVZ. This summer, I obtained the elemental composition of four plutonic lithic samples and used cathodoluminescence (CL) to identify their grain textures on the Scanning Electron Microscope.

Generally, compositional data gives us insight into the evolution of a magma and the genetic relationship between different rocks (Fig, 1). I found that one sample was compositionally comparable to an Ohakuri plutonic lithic studied by Brown (1998); two samples fell slightly above or below the crystal fractionation pathway at Ohakuri determined by Smithies et al. (2023), often overlapping with compositional data from plutonic lithics associated with the Whakamaru eruption (which occurred roughly 100,000 years prior to Ohakuri); and one sample was compositionally similar to glass within Ohakuri pumice. This suggests that our plutonic lithics originated in different parts of the magma system beneath Ohakuri, thus reflecting different stages of magmatic evolution. Not only that, but it provides evidence of an extensive magmatic system beneath Ohakuri where multiple episodes of melt extraction take place.

Taking a closer look at the mineral zircon using CL allowed me to get a better sense of elemental differences between plutonic lithics and magma system processes on a smaller scale (Fig. 2). I noted oscillatory zoning, which indicates differing conditions during distinct episodes of growth and dissolution. I also observed episodes of resorption, indicated by evidently anhedral crystal faces. Both of these processes are characteristic of magma systems, especially ones that experience magma extraction, new magma injection, and other processes that alter the elemental composition of the magma body. Along with these textural insights, I also was able to observe elemental differences within each zircon crystal. In particular, I noticed that lighter zones were often enriched in hafnium and uranium whereas darker zones were depleted in those elements but enriched in thorium. Future research could use electron microprobe analysis to obtain quantitative compositional data and could use EBSD methods to look for crystal settling.



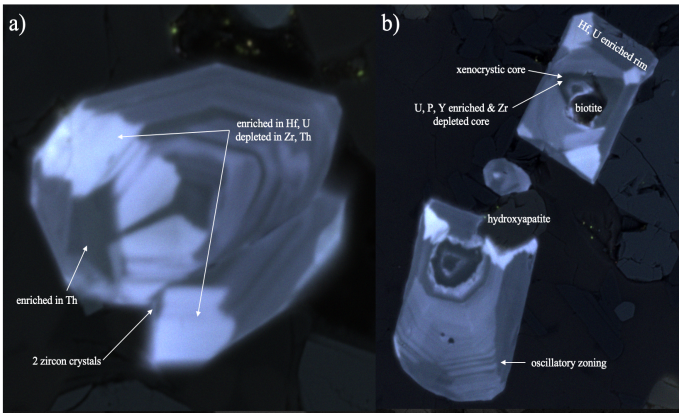


Figure 1. (left) Spider diagram of REE data from this study, Smithies et al. (2023) and Brown (1994). Normalizations are from Sun & McDonough (1995).

Figure 2. (right) CL images of zircon crystals from AtLi 9a.

Faculty Mentor: Professor Rachel Beane

Funded by the Surdna Foundation Undergraduate Research Fellowship Program

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